TURNITIN Microstructure and Mechanical Properties

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Microstructure and Mechanical Properties of Copper-Iron Fabricated by Mechanical Milling and Continuous Sintering

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Abstract. This research is to analyze the effect of mechanical milling on the microstructure and mechanical properties of copper-iron. The sample is fabricated by compacting, milling and sintering processes. Sintering process is carried out using continuous type machine with conveyor belt mesh and the furnace type is muffle. After that, it is cooled with natural water jacket process. Vicker hardness testing and tensile strength test is performed to determine the mechanical properties of copper-iron alloys that occur. The mean value of sample 1 hardness (before milling) was 39.8 HV. The mean value of sample hardness 2 (after milling) was 74.9 HV. The value of the yield strength (σ) of sample 1 is 17.597MPa, and the value of ductility (ε) is 0.119. The value of the yield strength (σ) of sample 2 is 18.547 MPa, and the value of ductility (ε) is 0.073. The test results and analysis showed that by shrinking the size of metal powder, by milling for 2 hours, the hardness and yield strength of the product can increase. Although, the product becomes more brittle which is indicated by the decreased ductility value.

Introduction

Nowadays, the automotive industry is dominating the world. One of the supporting industry is the automotive component. The component manufacturing process tries to make the product with lighter mass, good performance, durability and good reliability [1-6]. One of the parts used in four-wheeled vehicles is an electric starter component. One of the components in the electric starter is a starter bearing, which is made by metal powders.

The development of powder metallugy technology aims to improve the quality and efficiency of the products made [5-9]. One of the latest developments is to shrink the size of the metal powder grains. Some processes shrink the size of metal powders, among others, with mechanical milling that aims to form metal powder with a smaller grain size, so that can be obtained better quality when manufacturing using powder metallurgy technology [7]. One of the mechanical milling process is high energy ball milling which uses steel balls to pound metal powder [10-16]. Copper-iron metal powder that has been milling, used as research material. The study was conducted to determine the change of mechanical properties that occur in products with finer metal powder sizes. The results of this study are expected to improve product quality with copper-iron metal powder as a raw materials.

Experimental Method

Copper-iron powder was in mixed form 100 grams and it is separated into 2 parts (@ 50 grams). One part is for the milling and one part is the same as the initial condition. Copper-iron metal powder is milled using High Energy Ball Milling E3D (HEM-E3D) with two hours grinding time, 700 ~ 1400 rpm speed, stainless steel ball size 5 mm diameter, 5:1 ball to powder ratio, and 50 ml container volumes.

Green sample is compacted by Yoshizuka SP-20 High Speed with cold pressing type, carried out at room temperature. For driving and force distribution, the compacting machine utilizes the cam as the main driver distribution. Product emphasis techniques use double-pressing techniques. The die compacting equipment is a set of die sets, including die, upper punch, lower punch, and core rod. The green compact sample was sintered by TSFE7-6W Mesh belt sintering furnace. The sintering type is continuous with a mesh belt conveyor. The width of the mesh belt is 178 mm.

This hardness test is performed to determine the mechanical properties of alloys using Vickers hardness test of Mitutoyo type AVC-CO diamond-indexed with 5 kg load and it holds time for 5 seconds. This evaluation was carried out repeatedly to find the value of the hardness test results that are considered to represent the hardness value of the alloy. This tensile test is performed using Universal Testing Gotech AI-70005 servo control with 5 kN load and U60 Gotech data processing software. This evaluation is carried out on the sample until broken in one test. Sintered metallographic product is essential for studying the type and morphology of the sample microstructure. Therefore, we can understand the influence of the sample production process on the material properties of the sample. Microstructural testing of materials ranging from sample preparation, sample mounting, grinding & polishing process, etching with chemicals ($FeCl_3$), then analyzed using Olympus type DP21 digital camera microscope with 500x magnification.

Results and Discussion

The metal powder material used as the raw material is a mixture of metal powder with the composition shown in the following table:

Table 1. Compotition of Metal Powders

Elements	Fe	Cu	Zn	P	Sn	C	*Lube*
Compotition	47.54%	46.9%	2.0%	0.37%	2.1%	0.49%	0.6%

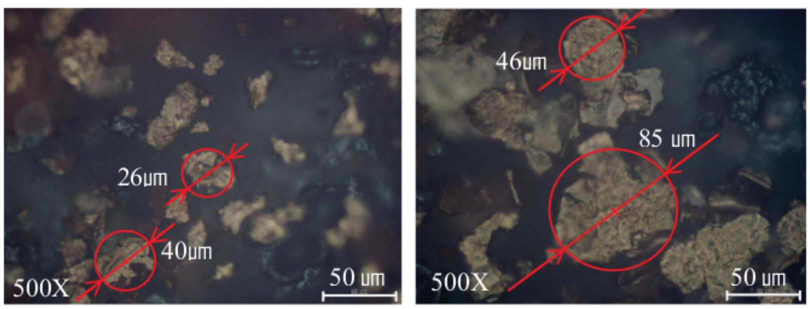

Figure 1. Microstructure of Cu-Fe before MM

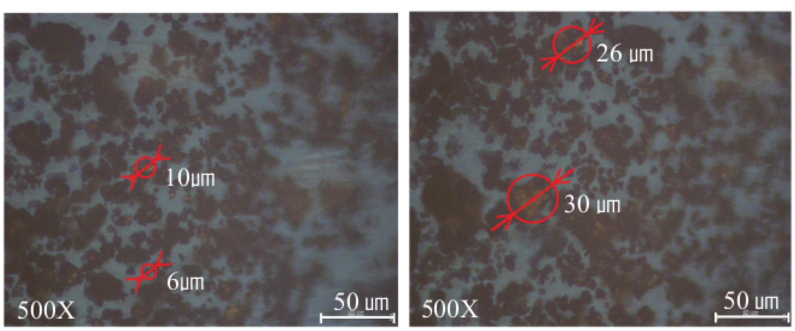

Figure 2. Microstructure of Cu-Fe after MM

The powder is milled with various size of grain. The size and shape of metal powders were analyzed by a microscope. Figure 1. shows the variation of Cu-Fe powders before mechanical milling. The size of the metal powder is between 26 μm to 85 μm. The shape of the powder is irregular and the surface of the powder is uneven. Figure 2. shows the size of the Cu-Fe powders after

MM, it is clearly showed that the grain is finer, the powder size is between 6 μm to 30 μm. The powder form is more regular and rounded and the powder surface is more evenly distributed.

The metal powder is formed using a compacting press machine into a green compact product. The machine parameters used are the same between sample 1 and sample 2, so the dimensions of sample 1 and sample 2 are the same. Products that have been made, are measured for their density. The calculation of product density uses the Archimedes principle. The value of green density is shown in Table 2.

Table 2. *Green density* of sample 1 (without MM) and sampel 2 (with MM)

No.	Mass [g]			Density
	A	B	C	[g/cm^3]
1	1.952	2.013	1.695	6.138
2	1.913	1.982	1.673	6.191

The density changes were measured on the sintered samples. From the measurement results, the density of the sintered samples obtained is shown on the following table.

Table 3. Density of sintered sample 1 (without MM) and sample 2 (with MM)

No.	Mass [g]			Density
	A	B	C	[g/cm^3]
1	1.935	1.995	1.681	6.162
2	1.890	1.952	1.649	6.238

The sintering process results in a decrease in product sample volume due to shrinkage. The shrinkage value is calculated by comparing the sample dimension after sintering against the sample before sintering (green compact).

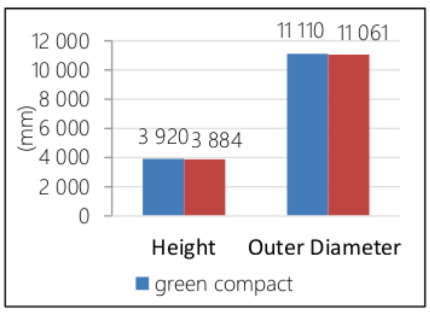

Figure 3. Dimension change on sample 1

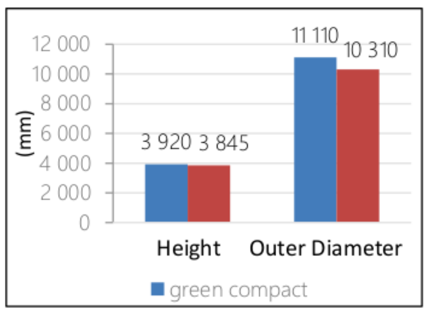

Figure 4. Dimension change on sample 2

The identification of the chemical composition of the alloy is carried out to determine the percentage of elements presents in the alloy after sintering. Table 4 shows the amount of chemical composition, where there is little change compared to the chemical composition of metal powders prior to sintering. This is because a number of lubricants burnt and evaporate during the sintering process.

Table 4. Compotition of Metal Powders

Elements	Fe	Cu	Zn	P	Sn	C
Compotition	48.31%	46.77%	1.99%	0.43%	2.01%	0.49%

Hardness testing was conducted as much as 10 times data in retrieval. Figure 5 shows the hardness value of sample 1. The lowest score is 38.1 HV and the highest hardness value is 41.5 HV. The mean value of hardness of sample 1 is 39.8 HV. Figure 6 shows the hardness of sample 2. The lowest value is 70.6 HV and the highest hardness value is 80.9 HV. The mean value of hardness of sample 1 is 74.9 HV. The data of hardness Vickers test shows that samples 2 is higher than in sample 1, this clearly shows that the product with Cu-Fe powders with smaller grain size resulting higher hardness. The tensile test is performed only once, because the sample will be broken in one test. The test is carried out by using the strength test machine until it reaches the yield strength value of the sample.

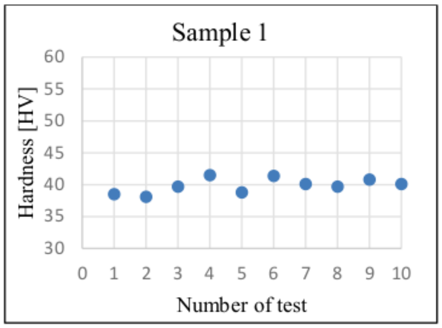

Figure 5. Vickers hardness of sample 1

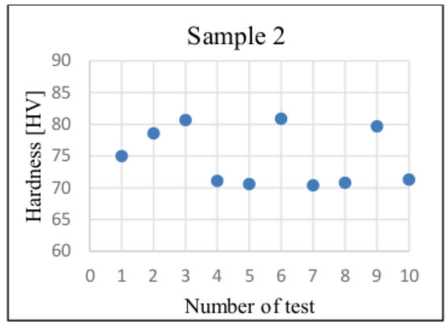

Figure 6. Vickers hardness of sample 2

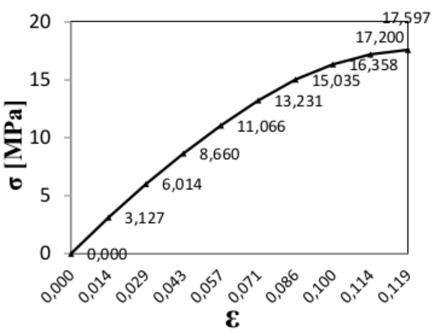

Figure 7. Tensile test of sample 1

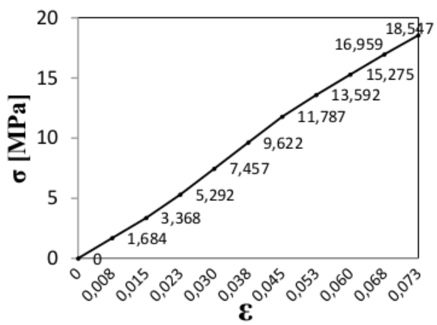

Figure 8. Tensile test of sample 2

From the data above it can be seen that the maximum strength value of sample 1 is 17,597 MPa, while maximum strength value of sample 2 is 18,547 MPa. However, the ductility value of the sample 2 is smaller than the sample 1. It shows a more brittle sample than sample 1. Microstructure observation was conducted to determine the physiological surface of the alloy formed. To know the distribution of the composition, sample 1 and sample 2 will be first tested on mounting to facilitate the microstructure observation process. Then, on the surface grinding uses the abrasive material of the abrasive to the grid of 1500. After that, it is polished with alumina paste to get a smooth surface and no scratches. Sample surfaces in etch use 25 gr $FeCl_3$, 25 ml HCl, and 100 ml aquades [9]. Blend surface magnified 500x to be analyzed.

Figure 9 shows the sample microstructure 1 (before milling) after sintering 850°C. The visible elements are copper (Cu) and iron (Fe) which have a large percentage (as seen in table 3) formed with large size (> 50 µm), and large pores (> 50 µm). For carbon element (C), it looks gray, with a small amount. For the other elements, such as zinc (Zn), phosphorus (P), and Tin (Sn), generally, they are at the grain boundaries of iron (Fe) and copper (Cu) elements [10]. Figure 10 shows sample surface microstructure 2 (after milling) 850°C sintering process. The visible elements are coppers (Cu) and iron (Fe) formed with a small size (< 50 µm), and small pores occur.

Summary

Based on the analysis conducted on the results of experimental studies on Copper-Iron, it can be summaryzed:

1. The size of the metal powder grain is minimized by means of milling time, from 26 µm to 85 µm to become 6 µm to 30 µm.
2. The hardness increases from an average of 39.8 HV to 74.9 HV, the yield strength (σ) increases from 17,597 MPa to 18,547 MPa, and the ductility (ε) decreases from 0.119 to 0.073, making it more brittle.

Excess product by using the material of metal powder material that has been in milling (smaller grain size) is increases the value of hardness and strength, so that product performance will be better. By the process of milling on metal powder, raw materials will increase the selling value in the manufacturing industry.

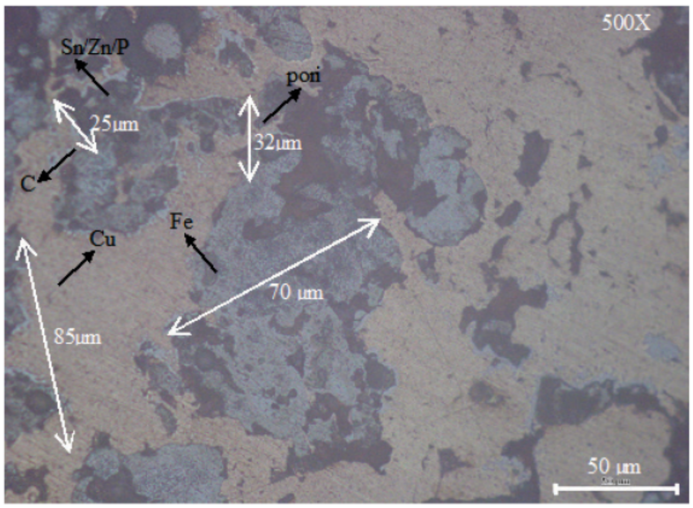

Figure 9. Microstructure of surface on the sample 1 (without MM) sintered temperature of 850°C

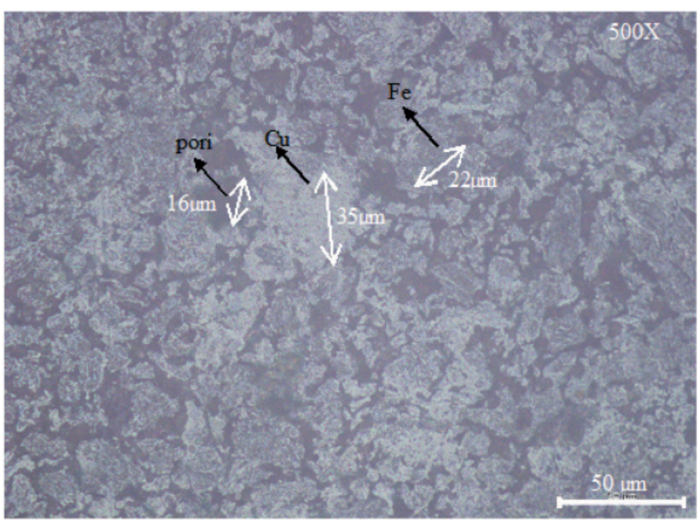

Figure 10. Microstructure of surface on the sample 2 (with MM) sintered temperature of 850°C

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